

## CROTALARIA, A NEW LEGUME FOR THE SOUTH

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INTRODUCTION<sup>1</sup>

About 600 species belong to the genus *Crotalaria*, and these are widely distributed in the several continents. Five species are native to the eastern United States. The greatest number occur in tropical and subtropical regions. This genus belongs to the legume family and is made up largely of herbaceous plants.

One species (*Crotalaria juncea* L.) is best known for the fiber it produces, although it is used for other purposes. In India, the Malay Peninsula, and on adjacent islands several species of *Crotalaria* have been recognized as having special value for soil improvement or green manure. The species most commonly used are *C. usaramoensis* Baker, *C. anagyroides* H. B. K., *C. juncea*, and *C. striata* DC. These species have also been grown in other parts of the world, and their use seems to be extending.

*Crotalaria striata* is the only species that has attained commercial importance in the United States. This species was first introduced in 1909 from eastern Africa at the request of the late C. V. Piper and was accessioned as S. P. I. No. 24119. The seed upon its arrival was sent to the Florida Agricultural Experiment Station at Gainesville, from which place its culture has gradually spread, and at the present time it is grown in that State extensively for green manure.

<sup>1</sup> Experimental work with *crotalaria* in the South has been carried on in cooperation with several State agricultural experiment stations. For results presented in this circular acknowledgment is made to the Florida Agricultural Experiment Station, Gainesville, Fla.; the Georgia Coastal Plain Experiment Station, Tifton, Ga.; the Sandhills Experiment Station, Columbia, S. C.; and the Coastal Plains Station, McNeill, Miss.

It is estimated that in 1929, 8,000 acres were planted. In Porto Rico *C. striata* is used extensively in citrus groves for cover and soil improvement, while in South Africa, Australia, the Philippines, and the Territory of Hawaii other species are recognized as having value as green manure and cover crops.

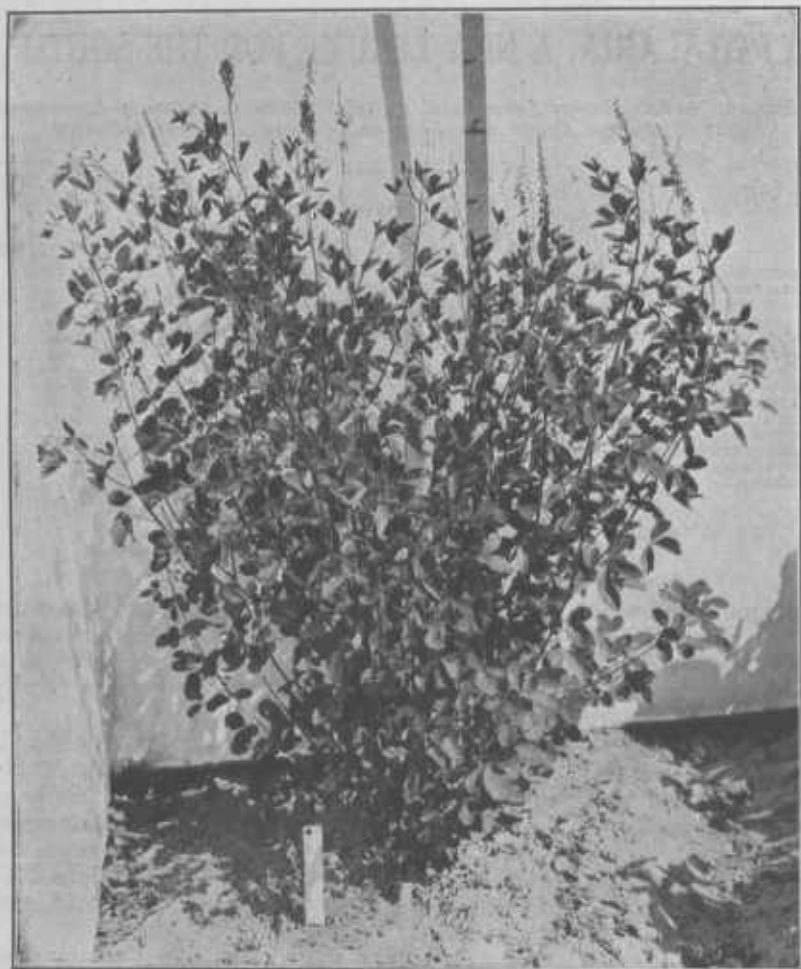


FIGURE 1.—*Crotalaria striata* plant in full bloom, showing general habit of growth

#### GENERAL DESCRIPTION

The *Crotalaria* species are mostly annuals, but many are perennials.

While the plants are mostly upright, some are semierect, others quite prostrate. There is great variation in plant height, from less than 1 foot to 15 feet, depending on the species. They are usually monofoliolate or trifoliolate, occasionally having more than three leaf-

lets. The branching varies with the species. Some have an upright central stem with little or no branching, while others are very profusely and finely branched. The species that have been used agriculturally are large, upright, and diffusely branched, with the exception of *Crotalaria juncea*, which is sparingly branched. (Figs. 1 and 2.)



FIGURE 2.—Plants of *Crotalaria spectabilis* with flowers and pods, showing general habit of growth

Some species, such as *Crotalaria retusa* L. and *C. lanceolata* E. Mey., mature a considerable quantity of seed early, within 100 to 140 days from the planting date. Many others are too late to mature seed, even under Florida conditions. *C. striata* and *C. spectabilis* Roth<sup>2</sup> represent an intermediate type as regards maturing seed, requiring 125 to 175 days before many pods are mature. Most species continue to set pods and mature seed all summer and fall,

<sup>2</sup> *Crotalaria sericea* Retz. is a synonym of *C. spectabilis* Roth. The latter name is used preferably in accordance with botanical nomenclatorial rules.

although *C. retusa* and *C. spectabilis* are more or less exceptions to this rule, as they mature at one particular time a large percentage of the seed produced during the season.

### CLIMATIC REQUIREMENTS

Most of the species of *Crotalaria* are tropical or subtropical in their requirements, and in the continental United States they are treated mostly as summer annuals. One native perennial species (*C. rotundifolia* (Walt.) Poir.) is found as far north as southern Virginia, while a native annual species (*C. sagittalis* L.) extends as far north as the New England States.

In experimental work with a number of species in Mississippi, Georgia, South Carolina, and Florida a temperature of 28° F. has been the minimum the growing plants will stand without damage.

While the adaptation and limitations of the various species have not been determined, limited experiments indicate that some species can be grown farther north than others. Of the two species tested somewhat extensively, *C. spectabilis* seems to be suited to conditions farther north than *C. striata*. At the Arlington Experiment Farm, Rosslyn, Va., *C. spectabilis* planted May 20, 1929, was in full bloom September 20, and had attained a height of 3 feet. *C. striata* during the same period made a growth of 8 to 10 inches with no bloom. At Gainesville, Fla., *C. anagyroides* is the only species tested that has perennated to any extent under field conditions. In a few cases when the winters have been exceptionally mild or the plants were growing in protected locations, the plants of *C. striata*, *C. usaramoensis*, and *C. incana* L. survived the winter.

### SOIL AND MOISTURE REQUIREMENTS

The work with *Crotalaria* species has not been extensive enough to determine definitely their limitations with reference to soil and moisture requirements. It is known, however, that they vary somewhat in this respect. While many species are native in tropical regions of heavy rainfall, none, so far as known, is adapted to wet situations. A well-drained soil is essential to good growth. The species that have been under experimental trial have indicated their ability to stand through droughty periods, and a few species are known which grow under extreme desert conditions.

In general most species of *Crotalaria* are adapted to sandy or light loam soils. Whether or not there may be species adapted to heavy clay soils is not known. Experimental work on heavy soils to date has indicated that the species tested are not well adapted to such soil. A few plantings on clay-loam soils have given fairly good results.

On poor sandy lands in the South several species have made a large growth in comparison with other legumes, and it is for such situations that they are attracting special attention.

### PALATABILITY TO LIVESTOCK

Many species of *Crotalaria* have a bitter taste in the green state and seem to be avoided by livestock. *C. striata* and *C. spectabilis* are included in this group. The latter is less bitter than the former.

It is not yet known what effect drying for hay may have on palatability, but a feeding test with crotalaria meal at Gainesville, Fla., (13)<sup>3</sup> suggests that crotalaria is more palatable in the cured state. Several species tested seem to be devoid of any unpleasant taste, even in the green state, and, although they have not yet been fed to livestock, may make good pasturage and hay. These are *C. gorensis* Guill. and Perr., *C. grantiana* Harvey, *C. maxillaris* Klotzsch, and *C. natalitia* Meissn. *C. usaramoensis* has been reported as being eaten readily by cattle and horses in the Netherland East Indies (6).

#### VALUE FOR FORAGE

Information regarding the value of crotalaria for forage is very limited. There is reference in literature to some species being browsed by livestock without injury, whereas a few species have been reported as poisonous.

At Gainesville, Fla., in 1927, an experiment (13) comparing crotalaria meal with alfalfa meal for milk production was carried out. The feeding period lasted 84 days. No injurious results were noted either during or after the experiment. The feed consisted of 12 pounds per day of the following mixture:

Crotalaria <sup>4</sup> or alfalfa meal	pounds	125
Corn meal	do	75
Ground oats	do	50
Cottonseed meal	do	50
Peanut meal	do	25

The crotalaria meal contained 8.58 per cent and the alfalfa meal 12.56 per cent of protein. It is stated in the report that "the crotalaria plants were too mature when cut to make a good quality of hay."

Six animals were used in the experiment, three being fed alternately crotalaria and alfalfa for periods of 28 days. The total milk production with the feed containing alfalfa was 3,577.3 pounds and with the feed containing crotalaria meal 3,416.7 pounds. This is 160.6 pounds in favor of the feed with alfalfa. Considering the quality of the crotalaria as reported, it seems that this plant may have considerable feeding value.

#### SPECIES INJURIOUS TO LIVESTOCK

A few species of *Crotalaria* have been reported as poisonous to livestock when browsed or fed green, and other species have been suspected. Conclusive experimental evidence of crotalaria poisoning, however, is lacking, and with the possible exception of *C. sagittalis* and *C. burkeana* Benth. the genus as a whole may be regarded as merely under suspicion, until more direct evidence is forthcoming.

*Crotalaria striata*<sup>5</sup> (8, 19, 20) has been reported as causing the death of both dairy cows and goats when eaten green, but no bad effects were noted when fed as dry hay (8, 13). *C. burkeana* has been reported as causing stiffness in the joints of cattle (3, 5, 12, 15), but apparently in some areas the effects of phosphorus starvation or deficiency have been attributed to this species. *C. sagittalis* (4, 11) has been reported as fatal to horses, with symptoms

<sup>3</sup> Italic numbers in parentheses refer to Literature Cited, p. 29.

<sup>4</sup> The species used in this experiment was *C. striata*.

<sup>5</sup> In the Australian report by J. C. Lewis this was referred to as *C. arborea*.

similar to those of loco weed (*Astragalus mollissimus* Torr.), when fed green. No trouble has been reported on this species for many years, however. Other species under suspicion are *C. rotundifolia* (Walt.) Poirr. (9), *C. incana* (18), *C. mitchellii* Benth. (18), *C. dura* Wood and Evans (12, 16), *C. juncea* (1), *C. globifera* E. Mey. (12), *C. zimmermannii* Baker (3), *C. polysperma* Kotschy (3), and *C. alata* Hamilton (2).

#### VALUE FOR GREEN MANURE

On the sandy lands at Gainesville, Fla., both corn and sweetpotatoes gave increased yields following *Crotalaria striata* in comparison with yields following a nonlegume. The 2-year average yield of corn following crotalaria was 19.68 bushels, whereas after a nonlegume the yield was 11.76 bushels. The 2-year average yield of sweetpotatoes following crotalaria was 58.86 bushels, and after a nonlegume 31.79 bushels. No other data regarding its effect on the yield of subsequent crops are available. However, wherever crotalaria will make good growth it is probable that its use for green manure will be beneficial.

In addition to planting corn following crotalaria in Florida and somewhat farther north, crotalaria can also be planted between the rows of corn at the last cultivation of the corn around June 1. A very good growth will be attained before frost.

Crotalaria volunteers very readily in corn, and if cultivation is not carried too late in the summer it will generally mature seed and reseed itself each year.

*Crotalaria striata* is grown extensively in the citrus groves of the sandy ridge section of central Florida as a summer green-manure crop. The main portion of seed planted in the State is in the young citrus groves, where its use is increasing steadily. The older groves furnish too much shade for crotalaria to grow properly. The yield of *C. striata* for green manure on these sandy lands has been greater than that of other legumes tried in comparison.

*Crotalaria spectabilis* and *C. striata* are used to some extent in the pecan groves of the coastal plains region of the Southeastern States. *C. spectabilis* in particular is becoming popular for this purpose in western Florida. Some interest is manifested in crotalaria as a green-manure crop for the early-potato areas of Florida. Crotalaria is particularly well adapted as a green-manure crop on land to be used for growing winter truck crops.

#### ORNAMENTAL VALUE

Many of the *Crotalaria* species have large showy flowers, and a few of these species are well suited for ornamental purposes. *C. retusa* has long racemes of showy yellow flowers with the back of the standard shaded or striped purple, and as the plants are comparatively small, it is well suited for borders. It also has value as a greenhouse plant for cut flowers. It comes into bloom early and continues until midsummer in Florida and until late summer and fall farther north. Its period of development is sufficiently short so that it can be used in the open as far north as Washington, D. C., where it will supply September bloom.

*Crotalaria usaramoensis* makes an excellent ornamental plant. It blooms freely and comparatively early and can be grown as far north as South Carolina and probably farther north. It blooms continuously like *C. retusa* but has a longer blooming period. It is also much larger than that species, and the flowers are more nearly solid yellow. In Florida *C. anagyroides* makes a good late-season plant for the open. At Gainesville it continues to bloom from August 1 until frost. It is upright and attains a height of 5 to 7 feet. The short, clustered racemes of large, bright-yellow flowers are very showy and attractive. For ornamental purposes there are no doubt other species equal to the ones mentioned.

#### USE AS A SMOTHER CROP

Observations at Gainesville, Fla., have shown *Crotalaria striata* and *C. spectabilis* to be excellent in combating weeds. Early-summer weeds such as Florida pursley (*Richardia scabra* St. Hil.), sand burs (*Cenchrus* spp.), and crabgrass (*Syntherisma sanguinalis* (L.) Dulac) often have covered crotalaria completely in its early stage of growth, but the crotalaria eventually has taken possession of the field. In Florida, crotalaria is highly regarded as a smother crop for nut grass (*Cyperus rotundus* L.) and other persistent weeds.

#### CHEMICAL ANALYSES

While but few chemical analyses of crotalaria have been reported, the information available indicates that it is high in protein and is similar to many other legumes in this respect. Tables 1, 2, and 3 give data with reference to nitrogen in crotalaria in comparison with other legume crops.

TABLE 1.—Yields of hay and calculated amounts of nitrogen in crotalaria and other legumes grown at the Florida Agricultural Experiment Station, Gainesville, Fla.

Crop	Yield (3-year average)	Nitrogen	Nitrogen per acre
	Tons	Per cent	Pounds
Crotalaria <sup>1</sup> .....	2.89	2.446	141.378
Beggarweed.....	.62	1.443	17.890
Velvetbean.....	.85	2.208	37.536
Cowpeas.....	1.10	2.015	44.330

<sup>1</sup> *C. striata*.

TABLE 2.—Percentage of nitrogen (dry basis) in tops and roots of crotalaria and other crops at the Florida Agricultural Experiment Station, Gainesville, Fla.

Crop	Tops	Roots
Crotalaria <sup>1</sup> .....	2.78	0.92
Beggarweed.....	1.64	1.07
Velvetbean.....	2.51	1.48
Cowpeas.....	2.29	1.65

<sup>1</sup> *C. striata*.



TABLE 3.—*Chemical analyses of crotalaria grown at the Florida Agricultural Experiment Station, Gainesville, Fla.*<sup>1</sup>

Species	Water	Ash	Fat	Protein	Carbo- hydrate	Fiber
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
<i>C. usaramoensis</i> .....	9.15	4.73	4.02	21.38	41.87	18.85
<i>C. spectabilis</i> .....	9.70	6.40	3.48	15.00	49.62	15.80

<sup>1</sup> The plants were 2 feet high when cut for analysis.

In studies by W. A. Leukel and reported by Stokes (14), young plants were found high in percentage of hydrolyzable carbohydrates and exceptionally high in total nitrogen. As the plants grew older the proportion of cellulose and lignin increased.

It is evident that these facts must be given consideration in determining the stage of development and amount of plant growth best suited to meet the needs of the crop to be fertilized or benefited. As stated by Leukel, Barnette, and Hester (7):

If a rapid accumulation of nitrates is desired, as in the case of vegetable crops, then the crotalaria plant should be incorporated with the soil in its early growth stages. If, on the other hand, a retarded accumulation of nitrates is desired, so that the crop or tree may make use of the nitrogen in the spring months, the plant should be in an advanced stage of growth and dry before it is incorporated with the soil.

#### LONGEVITY AND HARD SEED

Crotalaria seed in storage under favorable conditions has a long period of viability. Seed of several species 10 years old has been germinated, and it is probable that the seeds of other species have a similar life period. Under field conditions viable seed may remain in the ground for at least one season before germinating. This delay in germination is made possible by the presence of seed that has an outer seed coat impervious to moisture. Whether or not this seed will remain in the soil more than one season has not been determined, but it seems probable that such is the case. Viable seed that does not germinate promptly is commonly referred to as hard seed. In Table 4 is given the percentage of germination and hard seed in several species of Crotalaria. The seed referred to as scarified was placed on an emery board and rubbed for a few seconds with sandpaper.

TABLE 4.—*Germination and hard seed in Crotalaria species as shown by a 10-day germination test*

Accession No.	Name	Germination		Hard seed	
		Scarified	Not scarified	Scarified	Not scarified
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
F. C. 15529.....	<i>C. incana</i> .....	72	4	26	96
S. P. I. 30969.....	<i>C. retusa</i> .....	38	0	52	98
S. P. I. 64062.....	<i>C. spectabilis</i> .....	45	8	43	80
F. C. 15843.....	<i>C. striata</i> .....	50	18	25	62
F. C. 15912.....	do.....	61	13	32	83



## SOURCE OF SEED

Since the introduction of *Crotalaria striata* in 1909 and until 1926, the crotalaria seed used in this country was grown in Florida. The quantity, however, was comparatively small. With increased interest in the crop and demand for seed, other sources were sought. In 1927 and 1928 the greater part of the seed planted was imported from Porto Rico. This was *C. striata*.

In the Far East seed of several species are harvested and offered for sale in the trade, but, with the exception of *C. juncea*, so far as known none of these is harvested in large quantity.

## INOCULATION

There has been no difficulty in getting inoculation of crotalaria wherever seeded. The organism that inoculates *Crotalaria* seems to be generally distributed as shown by widely separated adaptation tests. Native species of *Crotalaria* are distributed throughout the eastern and southern United States and may be a factor in the distribution of the inoculating organism. Experience with all the species of *Crotalaria* tested thus far indicates that artificial inoculation is not necessary.

## USE OF FERTILIZERS

No experimental work has been attempted to determine the value of fertilizers for crotalaria. The excellent growth made without fertilizer by the few species that have been grown most extensively suggests that under most conditions fertilizers can not yet be used to advantage. In many places where crotalaria has been grown, however, it probably has had some benefit from fertilizers used on previous crops. The effect of fertilizers when used on crotalaria direct has yet to be determined.

## TIME AND METHOD OF SEEDING

*Crotalaria* has been seeded broadcast, in close drills, and in wide rows. (Figs. 3 and 4.) The latter method has been used particularly when the crop has been intended for seed. Broadcast stands have been reasonably satisfactory, but the use of a drill saves seed. The seed of all species being comparatively small (figs. 5 and 6), very little seed is required for seeding. In 4-foot rows 2 pounds per acre is sufficient. When sown in close drills (6 inches) 12 pounds per acre is advised, and for broadcast seeding from 15 to 20 pounds per acre should be used, depending on the condition of the seed bed. A thoroughly prepared seed bed with well-firmed soil is desirable, the seeding depth depending on the available soil moisture. In general, the seeding should be as shallow as possible, consistent with getting sufficient moisture to induce germination and to insure maintenance of subsequent growth.

The time of seeding will vary somewhat with latitude. In general, crotalaria should be planted about the same time as corn. From March 15 to April 15 is recommended for Florida, and from April 1 to April 30 for the other Gulf Coast States when growing for green manure and soil improvement or a seed crop. When growing for hay in Florida the seeding date should be June 15 to July 1, so

that the crop will not be ready to cut before the last of September or early October, when the best drying weather prevails. Farther north the date of planting should be a little earlier, provided it is desired to follow the practice of making hay during the drier fall period.



FIGURE 3.—A field planting of *Crotalaria spectabilis* in rows at McNeill, Miss.

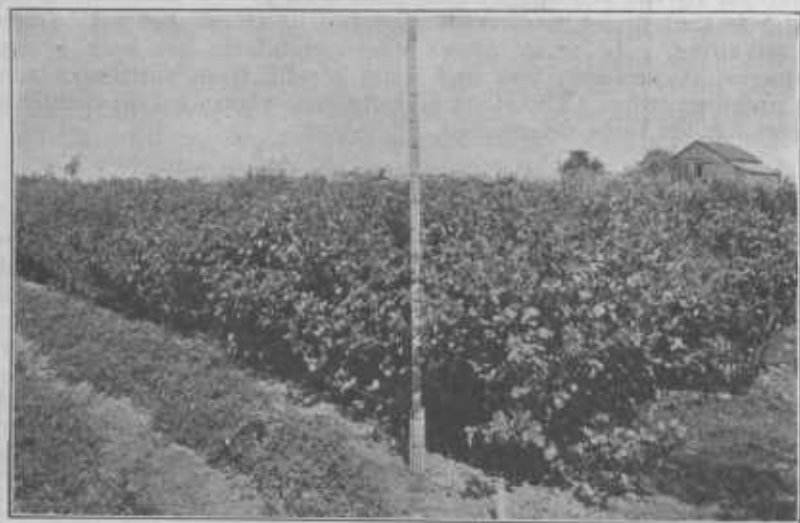


FIGURE 4.—A field planting of *Crotalaria striata* in rows at McNeill, Miss.

*Crotalaria* planted by June 1 in Florida and not disturbed before frost will mature an ample quantity of seed to reseed itself. Plantings made in citrus and pecan groves for soil improvement need not be replanted if a seed crop is allowed to mature each year, and generally much seed can be gathered for additional plantings or for market. The land should be disked lightly some time before March 1 in order to cover the seed scattered by the bursting pods.

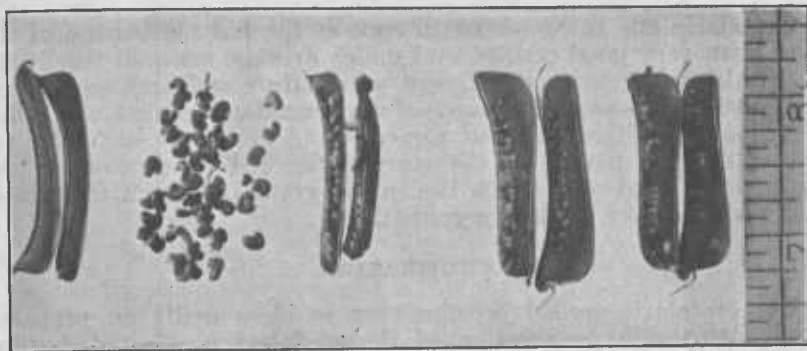


FIGURE 5.—Mature seed and pods of *Crotalaria striata*



FIGURE 6.—Racemes of flowers and mature pods of *Crotalaria striata*

*Crotalaria* can be broadcast in corn at the last cultivation of the corn with very good results, and under average seasonal conditions in Florida when sown this late it will mature sufficient seed to re-seed itself each season. Many of the *crotalaria* plants are killed by the early cultivations, but a good stand is usually secured after the cultivation period of the corn is finished on account of the presence of hard seed which lies in the ground through the winter and early summer without germinating.

#### CULTIVATION

For *crotalaria* seeded broadcast or in close drills on prepared land a thorough preparation of the seed bed is advised, but no cultivation should be given subsequent to seeding. Seedings in wide rows should be cultivated sufficiently to keep down weeds.

#### HARVESTING FOR FORAGE

For use as hay or for any similar purpose, *crotalaria* should be sown in thick stands close-drilled or broadcast. When grown from such seeding the erop can be cut with an ordinary mower and handled as other common hay crops. The stage of development at which the erop should be cut to insure the greatest feeding value has not been determined. Judging by experience with other legumes, cutting in full bloom probably is to be recommended when the forage is intended for cattle.

In order to have plants in the best state of development for hay during the early fall when weather conditions in the South are usually most favorable for haymaking, it is necessary to seed late. In Florida plantings should be made from the middle of June until July 1, in order to have *Crotalaria striata* ready for hay the latter part of September or early in October.

#### YIELD OF FORAGE

At Gainesville, Fla., on sandy Norfolk soil, *Crotalaria striata* for a 3-year average yielded 2.89 tons of dry forage, while cowpeas yielded 1.1 tons, velvetbeans 0.85 of a ton, and beggarweed 0.62 of a ton. At Lake Alfred, Fla., a point farther south, *C. striata* for two seasons averaged 3.69 tons, cowpeas 1.14 tons, velvetbeans 1.4 tons, and beggarweed 2.03 tons.

*Crotalaria spectabilis* at Columbia, S. C., in 1928, yielded 19,069 pounds in green weight, compared with 16,003 pounds for velvetbeans, 12,888 pounds for soybeans, and 8,769 pounds for cowpeas.

At McNeill, Miss., in 1927, *C. spectabilis* averaged 19,095 pounds green weight in experimental plots.

Tables 5 and 6 give the results of yields at various places.

TABLE 5.—*Crotalaria* forage yields in comparison with yields of other legumes

Forage plant	Place	Seasons grown	Yield, green	Yield, air dry
		Number	Pounds	Pounds
<i>C. striata</i> .....	Gainesville, Fla.....	3	-----	5,780
Do.....	Lake Alfred, Fla.....	2	-----	7,380
Do.....	Gainesville, Fla.....	1	39,324	12,084
<i>C. spectabilis</i> .....	Columbia, S. C.....	1	10,069	-----
Do.....	McNeill, Miss.....	1	19,095	-----
Do.....	Gainesville, Fla.....	1	12,760	13,662
Cowpea.....	do.....	3	-----	2,200
Do.....	Lake Alfred, Fla.....	2	-----	2,280
Do.....	Columbia, S. C.....	1	8,769	-----
Soybean.....	do.....	1	12,888	-----
Velvetbean.....	Gainesville, Fla.....	3	-----	1,700
Do.....	Lake Alfred, Fla.....	2	-----	2,800
Do.....	Columbia, S. C.....	1	16,003	-----
Beggarweed.....	Gainesville, Fla.....	3	-----	1,240
Do.....	Lake Alfred, Fla.....	2	-----	4,060

<sup>1</sup> Oven dry.

TABLE 6.—Effect of one, two, and three cuttings on the forage yields of *crotalaria* at the Florida Agricultural Experiment Station, Gainesville, Fla., in 1928

[Plots 10 by 33 feet were replicated three times; broadcast seedlings]

Species	Cut once, Nov. 15			Cut twice, July 19 and Nov. 15			Cut three times, July 19, Sept. 15, and Nov. 15		
	Green weight	Oven dry		Green weight	Oven dry		Green weight	Oven dry	
		Weight	Average percent- age of nitrogen		Weight	Average percent- age of nitrogen		Weight	Average percent- age of nitrogen
<i>C. striata</i> .....	Pounds 39,324	Pounds 12,084	2.07	Pounds 28,880	Pounds 6,568	3.16	Pounds 19,035	Pounds 4,166	3.10
<i>C. spectabilis</i> .....	12,760	3,662	1.44	5,205	1,305	2.06	-----	-----	-----
<i>C. usaramoensis</i> .....	28,508	10,172	1.58	10,063	3,182	3.05	-----	-----	-----
<i>C. lanceolata</i> .....	14,482	5,208	1.15	11,391	3,239	3.01	8,821	2,204	2.93

In the experiment reported in Table 6 *Crotalaria striata* and *C. spectabilis* were seeded at the rate of 30 pounds per acre, while *C. usaramoensis* and *C. lanceolata* were seeded at the rate of 15 pounds per acre. The resultant stands of the plants per unit area were *C. striata*, 243; *C. spectabilis*, 58; *C. usaramoensis*, 55; and *C. lanceolata*, 76. The *C. spectabilis* evidently contained much hard seed, as the germination was very poor, with a resulting poor stand. This was also true of *C. usaramoensis* and *C. lanceolata* to a lesser extent. Plants of *C. spectabilis* continued to emerge all summer. This gave *C. striata* a decided advantage, as a good early germination was secured, and consequently the yields were higher.

There are several points of interest in the preceding tables of yields. The *Crotalaria* species were cut back to a height of 4 to 6 inches, and all continued growth. The total yields for the season were much reduced by cutting back, although hay of much higher quality and higher protein content was secured by cutting two and three times per season.

As previously mentioned, rather late planting of *crotalaria* is advisable if desired for hay, as early-planted *crotalaria* will be very

coarse and stemmy by October, and weather conditions in much of the Gulf coast area ordinarily will not permit haying before late September.

#### HARVESTING FOR SEED

As most species ripen seed through a long period of time, harvesting the seed crop is difficult, and hand picking has been the common method of saving the seed in tropical countries. So little seed has been grown in the United States that no machinery for harvesting has been developed. Work in this connection needs to be undertaken, and varieties with better seed habits need to be developed. As previously pointed out, *Crotalaria spectabilis* has the best seed habits of the species tested, but even in this species ripening is over a long period of time.

As the pods burst and scatter the seed soon after maturity, it is necessary in all species to gather seed as it matures.

#### YIELD OF SEED

Very few data are available on the seed yields of *crotalaria*. The seed harvested in the Tropics is for the most part picked by hand from plants grown for green manure, and quantity yield under such circumstances is of secondary importance. Most species ripen their seed over a considerable period of time, so that for maximum yield the seed must be gathered in such a manner as not to injure the plants. In harvesting with machinery that cuts the crop, maximum yields can not be secured. *Crotalaria striata* ripens its seed over a long period of time, so that seed yields are comparatively low when harvested by cutting. *C. spectabilis* ripens its seeds in a shorter period than *C. striata*. The pods in all the species dehisce or break open more or less readily when ripe, and for this reason they must be handled promptly and carefully.

In Table 7 are given seed yields of several species of *Crotalaria* as grown at Gainesville, Fla. The seed will weigh about 60 pounds to the bushel.

TABLE 7.—Seed yields of *crotalaria* at the Florida Agricultural Experiment Station, Gainesville, Fla., in 1928

[The plots were 10 by 33 feet in size and were sown March 29, 1928. They were not replicated]

Species	Broadcast seeding <sup>1</sup>		2½-foot row seeding	
	Cut back July 19	Not cut back	Cut back July 19	Not cut back
	Pounds	Pounds	Pounds	Pounds
<i>C. striata</i> .....	80.6	242.6	141.0	281.8
<i>C. spectabilis</i> .....	249.6	598.2	347.5	370.2
<i>C. lanceolata</i> .....	138.0	657.2	214.8	388.7
<i>C. usaramoensis</i> .....	8.4	16.5	1.5	36.1

<sup>1</sup> The ratio of stand plant counts where broadcast was *C. striata*, 243; *C. spectabilis*, 58; *C. lanceolata*, 76; and *C. usaramoensis*, 55.

In the seed yields of *Crotalaria spectabilis* at McNeill, Miss., in 1927, S. P. I. No. 51839 on plots replicated three times yielded 890 pounds or 14.8 bushels per acre, while for an area of the same size

S. P. I. No. 64062 produced 992 pounds or 16.5 bushels in duplicated plots.

The summer of 1928 was exceptionally rainy, and the seed of *C. striata* did not develop properly, the thick stand making conditions very unfavorable for seed production. Approximately 50 per cent of the seed molded in the pods and did not develop.

As shown in Table 7, the seed yields were much reduced by cutting back the top growth. An interesting point in this connection is that seed matured on the new growth from the stubble at practically the same time as on the uncut plants.

#### INSECT ENEMIES

Crotalaria is host plant to several insects. In the United States the only ones doing appreciable damage are the bella moth (*Utetheisa bella* L.) and the pumpkin bug (*Nezara viridula* L.). The larvae of the bella moth develop in the pods and destroy the seed, doing considerable damage. They are more numerous and consequently do more damage early in the season than later. No control measures have been determined. Planting late and cutting back the first growth of early plantings would tend to throw the fruiting season late.

The pumpkin bug seldom does serious damage to the crotalaria plant. It is very fond of the seed pods and feeds on these almost exclusively, therefore the seed crop suffers most. When crotalaria is used for cover or green manure in citrus groves the pumpkin bug may go from the crotalaria to the citrus fruit, doing considerable damage. This is especially true when the crotalaria plants drop their pods, for any reason, such as frost, drought, or heavy damage by pumpkin bugs or other insects. The pumpkin-bug damage to citrus fruit has been studied by the entomologist of the Florida Agricultural Experiment Station (17), and control measures have been advised consisting of cutting back the crotalaria in August or earlier, but never cutting it late in the fall after the pods are formed. In the latter case the bugs, if present, will be driven to the citrus fruit. In other words, the crotalaria crop should not be allowed to go beyond the bloom stage before cutting. When handled in this way it will be necessary to reseed every year, but with low-priced seed this is no serious objection.

#### DISEASES<sup>6</sup>

##### ANTHRACNOSE

Anthracnose has been a conspicuous disease in crotalaria for the last few years and is caused by the fungus *Colletotrichum crotalariae* Petch. The disease is most commonly found on *Crotalaria striata* and *C. spectabilis*, probably more pronounced on the latter. The

<sup>6</sup> The section relating to crotalaria diseases was prepared by George F. Weber, associate plant pathologist, Florida Agricultural Experiment Station, Gainesville, Fla., and is based largely on work done in Florida. No specific studies have been reported from other stations in the United States, but diseased plants have been observed at stations in Georgia and South Carolina, and probably most of the diseases listed by Mr. Weber occur in these and other Southern States. In the Tropics of the Far East *Fomes lignosus* and *F. lamaoensis* have been reported as attacking crotalaria roots (10).



stems of the plants are attacked from the soil surface upward, and the bark is killed and sloughs away. The plant dies gradually, shedding the lower leaves, the shedding advancing upward. The entire plant finally succumbs, sheds all its leaves, and turns brownish black. The fungus produces fruiting structures and spores abundantly over the cankerous areas on the stem. These areas are also overgrown in most instances with a *Fusarium* species, which assumes a secondary more or less saprophytic rôle. This disease spreads from one plant to another and advances rapidly from the central source of inoculum. Where it occurs, it is severe in its attacks, but generally the loss is not great.

#### CERCOSPORA LEAF SPOT

The cercospora leaf-spot disease is caused by *Cercospora crotalariae* Sacc. Both *Crotalaria striata* and *C. spectabilis* are attacked by this disease, but it is not serious on the former. On the latter, however, it assumes considerable proportions and during the latter part of the summer has caused almost entire defoliation. The spots appearing on the leaves are more or less scattered. At first they are dark colored, slightly sunken, and irregular in outline, increasing in size as they grow older, often to a centimeter in diameter, and a large percentage develop whitish centers. The fungus fruits prolifically on both surfaces of the spots. The spots on *C. striata* are much smaller, usually round, sunken, and of tannish-brown color. This disease may be found also wherever the host plant is grown.

#### DAMPING-OFF

In the spring plantings of crotalaria there is considerable damping-off, caused by *Corticium vagum* B. and C. This trouble does not appear to be limited to any specific species of the host plant. The fungus attacks the seedlings at the soil line, girdling them, and as a result the plants are killed in very typical fashion. This disease is more pronounced in low, wet places, and a great amount of damage occurs during periods of wet, cool weather.

#### SOUTHERN BLIGHT

Southern blight, caused by *Sclerotium rolfsii* Sacc., is rather common and is well distributed throughout Florida, attacking crotalaria wherever it is grown, appearing more or less common on the more widely grown species, such as *Crotalaria striata* and *C. spectabilis*. The latter has experienced the greater losses. The fungus attacks the plants at almost any time during their development from the seedling stage to seeding, girdles the plants at the soil line, and eventually kills them, after which they turn brown, and if the plants are past the seedling stage they usually remain standing. The fungus produces innumerable small, round, brown sclerotia on the stem of the plant and in its immediate vicinity at the soil line.

#### GRAY MOLD

Gray mold, caused by *Botrytis cinerea* Pers., has been very conspicuous during past seasons on *Crotalaria spectabilis*. In the vicinity of Gainesville, Fla., this disease has caused losses averaging 3 to

5 per cent of the plants. The fungus attacks the plants following blossoming time, being prominent on the stalks and seed pods, and commonly forms spots on the leaves. It usually attacks the stems at the point of union of stem and peduncle of the seed pods, where brown lesions are formed. The lesions eventually girdle the entire stem. As the lesion develops in both directions from the original infection the killed area rapidly dries out and the bark breaks away from the woody portions of the stem. These lesions often involve from 2 to 10 inches of the stem, and after the lesion occupies an inch or more of the stem area the fungus develops conidia in abundance on the area involved. The seed pods are usually infected from either end, from which the fungus overgrows the remaining portions of the pod and develops fruiting bodies. The areas on the leaves are not so numerous, although they are often 2 centimeters or more in diameter and covered with fruiting bodies.

During 1929 this trouble was more conspicuous and caused greater losses than any of the other diseases of crotalaria with the possible exception of *Cercospora* leaf spot.

#### ALTERNARIA LEAF SPOT

*Alternaria* leaf spot, found occasionally on declining leaves, is caused by *Alternaria* sp. It is not conspicuous or of economic importance and is worthy of mention only.

#### HELMINTHOSPORIUM LEAF SPOT

*Helminthosporium* leaf spot, caused by *Helminthosporium* sp., has been collected a very few times and has not been found to be of any importance on any of the various species of *Crotalaria* grown. It is reported primarily because of its occurrence.

#### NEMATODE RESISTANCE

In experimental and extensive commercial plantings the *Crotalaria* species have been found immune to nematodes. This fact is of great economic importance in connection with any crop throughout the South.

#### DESCRIPTION OF SPECIES

The species included in this study are described in the following pages. General agronomic notes indicative of the probable value of the species under cultivation also are given. A key to the species is included to facilitate identification.

#### KEY TO THE SPECIES

Leaves monofoliolate.

Stipules large.

- |  |                       |
|--|-----------------------|
| Pod pubescent; flowers blue.....   | <i>C. verrucosa</i>   |
| Pod without pubescence; flowers yellow.....  | <i>C. mysorensis</i>  |
| Leaves with long pubescence.   |                       |
| Leaves with short pubescence.  |                       |
| Flowers many, in long terminal racemes;<br>under side of leaf with short pubescence..            | <i>C. spectabilis</i> |
| Flowers 2-3, in lateral and terminal racemes; both sides of leaf with midlong<br>pubescence..... | <i>C. alata</i>       |

Stipules small or wanting.

Pod pubescent with long hairs.

Flowers in long lax racemes; pods exserted.

Racemes 6-10 flowered..... *C. tetragona*

Racemes 12-20 flowered..... *C. juncea*

Flowers in short lax racemes; pods inclosed.

Leaves silky villous, 5 cm. long..... *C. vuletonii*

Leaves silky pubescent, 10 cm. long..... *C. fulva*

Pod with short pubescence (often visible with hand lens only).

Flowers 25 mm. long..... *C. candicans*

Flowers 35 mm. long..... *C. cunringtonhamii*

Pod without pubescence.

Pods inclosed by calyx.

Flowers 9 mm. long; pod 12-14 mm. long;

calyx with short gray pubescence..... *C. albida*

Flowers 20 mm. long; pod 15 mm. long;

calyx with long brown pubescence..... *C. calycina*

Pod exserted.

Flowers 15-17 mm. long; pod 35 mm. long..... *C. retusa*

Flowers 10 mm. long; pod 17-18 mm. long.

Perennial; prostrate..... *C. rotundifolia*

Annual; semierect..... *C. sagittalis*

Leaves trifoliate.

Pod pubescent with long hairs.

Standard glabrous outside; stems with very short pubescence.....

*C. incana*

Standard pubescent outside; stems with long pubescence.

Pod 15-20 mm. long..... *C. oocarpa*

Pod 30-40 mm. long..... *C. polysperma*

Pod with short pubescence (often visible with hand lens only).

Flowers 20 mm. or more long.

Flowers in terminal racemes..... *C. intermedia*

Flowers axillary..... *C. axillaris*

Flowers 12-20 mm. long.

Leaflets broadly obovate.

Stems of plant canescent..... *C. capensis*

Stems of plant green..... *C. striata*

Leaflets elongate or linear.

Petiole 8-10 mm. long; leaflets 5-10 mm. wide; seed 2 mm. long.....

*C. mundryi*

Petiole 15 mm. or more long; leaflets usually more than 10 mm. wide; seed 2.5-4 mm. long.

Pod 12-18 mm. long..... *C. maxillaris*

Pod 30-35 mm. long..... *C. anagyroides*

Flowers less than 10 mm. long.

Pod spherical, small..... *C. sphaerocarpa*

Pod elongated.

Flowers striate.

Racemes long.

Flowers 9-11 mm. long..... *C. sp. 60305*

Flowers 7-9 mm. long.

Leaflets 40-80 mm. long..... *C. lanceolata*

Leaflets 11-35 mm. long..... *C. mesapontica*

Racemes short.

Stems and under side of leaflets nearly glabrous.....

*C. astragalina*

Stems and under side of leaflets pubescent.

Standard and keel 5 mm. long.....

*C. vallicola*

Flowers not striate.

Standard pubescent outside; pod 10 mm. long----- *C. grantiana*

Standard not pubescent outside; pod 14 mm. or more long.

Pod 14 mm. long; plant mostly spreading; leaflets obovate----- *C. pumila*

Pod 17 mm. long; plant very erect; leaflets linear----- *C. goreensis*

Pod without pubescence.

Flowers in long terminal racemes----- *C. usaramoensis*

Flowers 1-2, on lateral branches, a few terminal----- *C. natalitia*

#### *Crotalaria alata* Hamilton.

Plant erect, 3-10 decimeters in height, with moderately heavy stems, openly to densely branched, clothed throughout with dense gray pubescence; stipular wing, broad and extending down the stem nearly to the leaf; leaves simple, midlarge, up to 7 cm. long by 2-3 cm. wide; flowers yellow, small, 11 mm. in length, and but slightly exerted from the calyx, 2-3 in each raceme; pod long stalked, smooth, 35-45 mm. long; seed small, 3 mm. long, very dark brown or black.

This species flowers midearly in comparison with other species. At Gainesville, Fla., it has bloomed about the middle of July, and at Columbia, S. C., a month later. Seed has ripened throughout September. At Gainesville, Fla., and McNeill, Miss., it has made a fairly good growth, but does not promise to be of as much value as several other species. At Columbia, S. C., it has not done so well as in Florida and Mississippi.

#### *Crotalaria albida* Heyne.

Plant semlerect, bushy, 3-6 decimeters high; stems round and with minute gray pubescence, finely branched, making a dense plant; stipules wanting; leaves simple, linear or oblanceolate, 2-5 cm. long, gray silky pubescence beneath; racemes mostly terminal, 6-20 flowered; flowers yellow, inclosed or scarcely exerted, 9 mm. long; calyx 9-10 mm. long, conspicuous, teeth divided nearly to the base; pods small, 12-14 mm. long, oblong; seed very small, 1.5-2 mm. long, brown, matures very late.

In southern Florida where this species has been tested it has grown to be a small bushy plant that suggests its possible value as a cover crop. It has bloomed freely but matured but little seed. It has not been grown elsewhere.

#### *Crotalaria anagyroides* H. B. K.

Plant erect, large, attaining a height of 3 meters; stems well branched, finely pubescent on young growth, becoming woody with age; stipules none; leaves trifoliate; leaflets large, 10 cm. long by 3½ cm. wide, oval, tending to be pointed at both ends, little or no pubescence; flowers large, 20 mm. long, yellow, clustered in terminal and lateral racemes, quite showy; calyx tube 5 mm. long; calyx teeth 5 mm. long; pod with short appressed pubescence, tending to cylindrical, inflated, 30-35 mm. long; seed midlarge, 4-6 mm. long, light color, greenish brown to yellowish brown, matures late.

This is a large-growing species, with good foliage and a symmetrical spread of branches, which makes it an attractive plant. Its bright yellow, showy flowers clustered at the ends of the branches make it of possible value as an ornamental in Florida. It requires a long season for its development and therefore is less desirable

farther north. It is a very sparse seeder under Florida conditions and too coarse for best forage.

*Crotalaria astragalina* Hochst.

Plant erect, up to 6 decimeters high; stems small, subglabrous; stipules none; leaves trifoliate; leaflets linear, 4-7 cm. long, 5 mm. wide, glabrous above, subglabrous beneath; flowers in short terminal and lateral racemes; calyx 3 mm. long, sparingly pubescent, the teeth about equaling the tube; corolla 8 mm. long, the standard striate with heavy purple lines, the tip appearing almost solid purple; pod long oval or cylindrical, 2 cm. long and 6 mm. wide, finely pubescent; seed 2 mm. long, light color, matures late.

This is a small-growing plant which has been grown at Gainesville, Fla., only, and appears to be of inferior value.

*Crotalaria axillaris* Dryand.

Plant erect, 3-9 decimeters high, moderately branched; stems finely puberulent; stipules very small or wanting; leaves trifoliate on long petioles, up to 7 cm. long and 3 cm. wide, glabrous above, sparsely pubescent beneath; flowers large, 20 mm. long, yellow, finely striped with purple lines, single in leaf axils, the terminal clustered; calyx tube very broad, 3 mm. long; calyx teeth dentate, 6 mm. long; pod large, up to 5 cm. long, sparsely pubescent; seed 3 mm. long, mostly light brown, matures late.

This species has been grown in the open at McNeill, Miss. While not so free a grower as some others, it may be of some importance, and further tests should be made.

*Crotalaria calycina* Schrank.

Plant semiprostrate to semierect, 3-6 decimeters high, sparingly branched; stems densely pubescent; stipules very small; leaves simple, long linear, 10-11 cm. long by 1.5 cm. wide, glabrous above, pubescent beneath; flowers large, 20 mm. long, pale yellow, turning brown on drying, entirely inclosed; calyx large, clothed in long brown pubescence; teeth linear, 20-25 mm. long, divided to the base; pods small, inflated, obovate, glabrous, 1.5 cm. long, inclosed; seed small, 2-2.5 mm. long, light color, matures late.

The small growth made by this species limits its possible use. It has been grown only in southern Florida, where it may have possible value as a cover-crop plant. No seed matured at Coconut Grove, Fla.

*Crotalaria candicans* Wight and Arn.

Plant erect up to 3 meters or more in height, freely branching; stems stiff, clothed with dense brown pubescence; stipules none; leaves simple, short petioled, large, 10-12 cm. long and 4-6 cm. wide, fine dense silky pubescence on both sides; calyx 12 mm. long, deeply bilabiate, teeth acuminate to lanceolate; flowers exserted, 25 mm. long; standard densely silky on the back; pod 2.5 cm. long, subsessile, nearly glabrous; seed large, 5 mm. long, light to dark brown, matures very late.

A good growth has been made by this species in both southern Florida and southern Mississippi. It requires a very long season. No seeds were developed at McNeill, Miss. The stems are too coarse for good forage but make good green manure.

*Crotalaria capensis* Jacq.

Plant 6-20 decimeters high, erect, branching freely; stems hard with age, round, subglabrous; stipules deciduous; leaves trifoliate; leaflets obovate, up to 2-3 cm. long, both sides nearly glabrous; flowers large, yellow, 15 mm. long, 6-20 in lateral and terminal racemes; calyx tube 5 mm. long; calyx teeth 6-8 mm. long; pod distinctly stalked, 3-4 cm. long, 6-7 mm. thick; seed 5 mm. long, brown, matures very late.

The late season and woody texture of this species makes it of less promise than the more nearly herbaceous and free-seeding species. At the various places where it has been tested it has grown freely but has bloomed sparingly and developed no seed.

*Crotalaria cunninghamii* R. Brown.

Plant semierect, 3-9 decimeters in height, becoming woody with age; stems finely pubescent, mostly round and moderately branching; stipules small or wanting; leaves simple, large, broadly ovate, 4-8 cm. long, densely tomentose on both sides; racemes terminal, usually short and dense; flowers large, 35-40 mm. long, yellowish-green color more or less streaked with dark lines; calyx pubescent, 5 mm. long; calyx teeth 5-8 mm. long; pod coriaceous, 4 cm. long; seed 3 mm. long, drab or light brown.

This species has been grown under greenhouse conditions only. It apparently requires a very long season.

*Crotalaria fulva* Roxb.

Plant erect, 9-12 decimeters high, branching from a central stem; stems with dense silky pubescence; stipules few on young stems, small; leaves simple, broadly linear, 10 cm. long and 2.5-3 cm. wide, short silky pubescence above and below, appearing variable on each half of the leaf with different direction of light; flowers few in lax lateral and terminal racemes; calyx 1.5 cm. long, teeth large, foliaceous, inclosing the mature pod, villous; corolla exerted from the calyx; standard lightly pubescent on the back, much longer than the wings or keel, yellow with darker shading and more or less definite striations; pod oval, 1.5 cm. long, pubescent; seed large, 4 mm. long, brown, matures very late.

While this species has made a good growth its late season makes it less promising than many other species. In southern Florida it developed a fairly good crop of seed.

*Crotalaria goreensis* Gulll. and Perr.

Plant erect, 9-18 decimeters high, moderately branched, many leaves on main stem which with the large stipules make it appear quite leafy; stems finely pubescent and lightly sulcate; leaves trifoliolate, the central leaflet longer than the laterals, and linear to linear oblong or linear obovate, up to 4-6 cm. long and 1-2 cm. wide, glabrous above, sparingly short pubescent beneath; stipules foliaceous, acuminate, 1.5 cm. long; flowers few in lateral capitate racemes or many in dense terminal racemes; calyx finely pubescent, broadly campanulate, 4 mm. long, the wide acuminate teeth about equaling the tube; corolla 10-12 mm. long, yellow with considerable rose red on standard and wings; pod oval, 17 mm. long; seed 3.5 mm. long, reddish brown, matures very late.

A fairly good growth has been made by this species, which is very leafy and branches profusely from the crown. In habit of growth it is a good forage type; the leaves and stem have no bitter taste, but its seed production is low.

*Crotalaria grantiana* Harvey.

Plant erect, 6-9 decimeters high and ramosely branched, making it dense and bushy; stems finely pubescent; stipules very small; leaves trifoliolate; leaflets cuneate obovate, 10-20 mm. long and 4-8 mm. wide, upper side glabrous, lower side pubescent; flowers yellow, 7-9 mm. long, 1 or 2 in axils of the leaves or 3-5 in terminal lax racemes, outside of standard pubescent; calyx tube 2 mm. long; calyx teeth 2 mm. long; pod small, 9-11 mm. long, finely pubescent; seed small, 2 mm. long, brown, matures midlate.

As grown at Columbia, S. C., Tifton, Ga., and Gainesville, Fla., this species has numerous fine stems and is very leafy. It seems to lack the bitter taste of most other species and may make good forage, sets seed readily, and matures in good quantity. At Columbia, S. C.,

and Gainesville, Fla., it has been in bloom the first half of August and ripened seed the last of September.

*Crotalaria incana* L.

Plant erect, 6-18 decimeters high, divaricately branched, but forming a rather bushy plant; stems clothed in fine silky hairs; stipules very small; leaves trifoliate; leaflets broadly obovate to nearly oval, up to 3-4 cm. long, 2-2.5 cm. broad, glabrous above, sparse silky pubescence beneath; flowers yellow, 15 mm. long, about half again as long as the calyx; calyx teeth about three times as long as calyx tube; pod linear oblong, 32-35 mm. long and 8-10 mm. wide, turgid, clothed with spreading hairs; seed large, 4.5 mm. long, greenish brown to dark brown; matures midearly.

The stems of this species seem a little woody for the best forage. However, it makes a good growth, is well adapted to a wide range of conditions, and is a free seeder. At Gainesville, Fla., it has been in bloom the last of May, ripening seed in July. At Columbia, S. C., it has been about a month later. The main crop of seed matures somewhat later than the dates given.

*Crotalaria intermedia* Kotschy.

Plant erect, 9-18 decimeters high, moderately branched, stems terete, subglabrous; stipules wanting; leaves trifoliate; leaflets linear, glabrous above, subglabrous below; 8-14 cm. long, and 1-1.5 cm. wide; racemes lax, terminal, 15-30 cm. long; flowers up to 2 cm. long, yellow, the standard conspicuously veined with purple; calyx 5 mm. long, broadly campanulate, subglabrous; calyx teeth shorter than the tube; pod large, 5 cm. long, 1.5 cm. broad, inflated, little or no pubescence; seed 3 mm. long, mostly very light color, matures mid-late.

At all the stations where this species has been tested it has made a good growth and volunteers readily. It is not so leafy as *Crotalaria grantiana* or *C. maxillaris* and is somewhat coarser than those species. It makes a good growth farther north than *C. striata*, is a good seed producer, and has fairly good seed habits. At Gainesville, Fla., it has bloomed in July and August and ripened seed in August and September. In Georgia and South Carolina it has not ripened seed until October and November.

*Crotalaria juncea* L.

Plant erect, 2-4 meters tall, but little branched, often single upright stalks with no branches; stems terete, sulcate, with silvery gray pubescence; stipules none or very small; leaves simple linear or linear oblong, very finely pubescent on both sides, averaging up to 12 cm. long and 2 cm. wide; racemes lateral and terminal, lax, 12-20 flowered; calyx 2 cm. long, densely clothed with fine pubescence, teeth extending nearly to the base; flowers large, 3 cm. long, yellow; pod 3 cm. long and 1 cm. wide, inflated, clothed in dense fine pubescence; seed large, 4-5 mm. long, light to dark brown, matures very late.

This species is very variable, some varieties being much more branched than others. It is too coarse for good forage but makes a good green-manure plant. In India and adjacent tropical regions it is used for fiber as well as green manure. While it blooms from midsummer on, it sets no seed pods until late fall. It is a very sparse seeder under conditions in the United States.

*Crotalaria lanceolata* E. Mey.

Plant erect, 7-12 decimeters high, well branched; stems small, terete; leaves trifoliate; leaflets linear, 4-8 cm. long, 6-8 mm. wide, tip obtuse or rounded, mucronate, glabrous above, sparingly pubescent beneath; stipules none; flowers in long terminal racemes; calyx tube broadly campanulate, 3 mm. long, lightly



pubescent; calyx teeth acuminate, 2 mm. long; corolla 9 mm. long, yellow, standard and wings striate with purple lines; pod cylindrical, 3 cm. long, finely pubescent; seed 2.5-3 mm. long, light or reddish brown, matures midearly.

Next to *Crotalaria striata* and *C. spectabilis*, this has been the most extensively tested species. The general habit of growth is favorable for forage, but the plant has a bitter taste. For green manure it compares favorably with *C. striata*, although it does not make so large a growth. At Gainesville, Fla., it has bloomed about the middle of July and ripened seed the middle of August. It will mature two good crops of seed in one season in Florida.

*Crotalaria maxillaris* Klotzsch.

Plant erect, 6-10 decimeters high, with long suberect branches; young stems finely pubescent; stipules small, setaceous; leaves trifoliolate; the central leaflet larger than the lateral and about 3.5 cm. long and 1.5 cm. broad; apex rounded, glabrous above, short, sparse pubescence below; flowers in lax terminal racemes, 15-30 cm. long; calyx 5-7 mm. long, teeth lanceolate, cuspidate, reaching more than halfway down; corolla yellow, 18 mm. long, standard lightly striated and silky outside; pod subsessile, 12-18 mm. long and 6-10 mm. wide, finely pubescent; seed nearly 3 mm. long, variable brown, matures midlate.

The general habits of this species make it well adapted for forage purposes. Like *Crotalaria grantiana*, it has no bitter taste and may make good hay and green forage, making good growth farther north than most species and having very good seeding habits.

At Gainesville, Fla., it has bloomed about the middle of August and ripened seed the first of October. At Columbia, S. C., it has been about 15 days later than at Gainesville.

*Crotalaria mesopotamica* Taubert.

Plant erect, 6-12 decimeters high, ramose, lightly pubescent; stipules small or wanting; leaves trifoliolate; leaflets linear, oblong to elliptic, 11-35 mm. long and 4-8 mm. wide, upper side glabrous, under side lightly pubescent; raceme terminal and lateral, many flowered; calyx 3 mm. long, hirsute; flowers 8 mm. long, standard strlate; seed 2.5 mm. long, light color.

Plants of this species have been grown in the greenhouse at Washington, D. C., for over a year, and while they have flowered freely, no pods have set. Plants were established in the open at Gainesville, Fla., late in the season of 1929, but no seed was formed. This species has excellent general habits for forage, but its value for this purpose has yet to be demonstrated. It has a bitter taste in the green state.

*Crotalaria mundyi* Baker.

Plant erect, 6-12 decimeters high, bushy, with many branches from lower part of main stems; stems terete, finely pubescent; stipules small, setaceous; leaves trifoliolate, linear, up to 2.5 cm. long, 5 mm. wide, glabrous above, finely pubescent beneath; flowers 18 mm. long, yellow, in lax racemes; standard finely pubescent on outside, purple strlate; wings and keel shorter than standard; calyx 5 mm. long, teeth equalling the tube, finely pubescent; pod 17-18 mm. long, 5-7 mm. wide, very finely pubescent; seed 2 mm. long, light to dark brown, matures late.

In flower and pod this species is much like *Crotalaria maxillaris*, but it is more upright and makes a more compact growth than that species. It also has a later season and seems less well adapted to United States conditions. It matured seed as far north as Columbia, S. C.

*Crotalaria mysorensis* Roth.

Plant 1-9 decimeters high, erect, moderately branched; stems terete, densely silky with long hairs; stipules linear, foliaceous, persistent, 2-3 cm. long; leaves simple, linear-oblong to long ovate rounded at the apex, 5-7 cm. long, 1.5-2 cm. wide, clothed with long silky pubescence; racemes terminal and lateral, 15-20 cm. long, few flowered; calyx 15-20 mm. long, teeth long, acuminate, and extending nearly to the base; corolla yellow, not exerted; pod oblong, 3.5 cm. long by 2 cm. wide, inflated; seed 3 mm. long, dark brown or nearly black, matures midlate.

This rather coarse species has made too little growth to suggest any special value. At Columbia, S. C., it has bloomed the last of July and ripened seed by the middle of October. At Gainesville, Fla., it has been somewhat earlier. At both places it has set a fair amount of seed.

*Crotalaria natalitia* Melssn.

Plant upright, 1-2 meters high, openly branched; stems terete, lightly sulcate, very finely pubescent; leaves trifoliolate, the central leaflet longer than the laterals and linear to linear obovate, up to 4 cm. long and 1 cm. wide, glabrous above, sparingly pubescent beneath; stipules foliaceous, 1-1.5 cm. long, acuminate; flowers 1-4 on lateral stems or few in terminal lax raceme; calyx glabrous, very broadly campanulate, 7-8 mm. long, teeth broadly dentate and slightly shorter than the tube; corolla 15 mm. long; wings and standard quite wide and nearly of equal length, tinged with purple and somewhat striate; pod inflated, 3.5 cm. long and 10-12 mm. wide, glabrous; seed 4 mm. long, brown, matures late.

This species has made good growth, but it has not been tested sufficiently to determine its value. Its late season of maturing makes seed production uncertain. At Gainesville, Fla., and other places where it has been tested, it has not come into bloom until after the first of October and has matured comparatively little seed.

*Crotalaria oocarpa* Baker.

Plant semidecumbent, bushy, 6-9 decimeters high; stems with dense midlong rufous pubescence; stipules very small, setaceous; leaves trifoliolate; leaflets up to 5 cm. long and 2 cm. wide, narrowed at the base and with pointed apex, densely pubescent or villous on both sides; flowers in dense terminal racemes; calyx villous, 6 mm. long, the wide teeth about equaling the tube; corolla 12-15 mm. long, yellow, standard and wings purple or purple striate, standard pubescent; pod inflated, 3.5 cm. long and 10-12 mm. wide, glabrous; seed 4 mm. long, brown, matures late.

This species has been grown in Florida only, maturing seed at Coconut Grove, in the southern part of the State. Its general habits and growth suggest that it may have value as a cover crop.

*Crotalaria polysperma* Kotschy.

Plant erect, 9-12 decimeters high, divaricately branched; stems densely rufo-villous; stipules linear or setaceous; leaves trifoliolate, leaflets oblong ovate, tending to be acute at both ends, finely pubescent on both sides; racemes lax, 2-8 flowered; calyx 1.5-2 cm. long, teeth twice as long as tube; corolla yellow, standard lightly striped purple and densely silky on the back, as long as the calyx; pod 3-4 cm. long, brown, matures midlate.

While making a fairly large growth, this species is not so vigorous as many others and appears as a comparatively light producer of both forage and seed.

*Crotalaria pumila* Ortega.

Plant perennial, decumbent to semierect, moderately to profusely branched; stems 3-6 decimeters long, terete, branched, nearly glabrous; stipules small; leaves trifoliolate; leaflets narrowly obovate to cuneate, 1-2 cm. long, 7-9 mm.

wide, mostly emarginate, glabrous above, very fine sparse pubescence beneath; calyx 5 mm. long, teeth slightly longer than the tube, minutely pubescent; corolla yellow, 8-9 mm. long; pods 1-1.5 cm. long, 7 mm. wide; seed small, 3 mm. long, light color, matures midseason; a native American species.

Under cultivation this species, which has been tested in southern Florida only, has made a good growth, producing many stems which are very leafy. It is of good forage type and may have value for this purpose.

*Crotalaria retusa* L.

Plant erect, 3-6 decimeters high, sparingly or moderately branched; branches divaricate; stems terete, with fine grayish pubescence; stipules small, setaceous; leaves simple, oblanceolate to obovate, 6-12 cm. long and 2-6 cm. wide, sessile, glabrous above, very fine pubescence beneath; flowers in lax terminal racemes, 15-20 cm. long; calyx 1.5 cm. long, the broad teeth exceeding the tube; corolla yellow, standard 2.5 cm. long, with purplish tinge, exceeding the calyx; pod linear oblong, 4 cm. long, 1 cm. wide, glabrous, turning black in weathering; seed large, 4-5 mm. long, light brown to almost black, matures in midseason.

While having rather heavy stems and an open habit of growth, this species is very attractive when in flower. It blooms more or less continuously and flowers early in comparison with other species. It has little value as forage and on account of its small growth will probably be found inferior to many other species for cover-crop and green-manure purposes. It is a very profuse seeder.

*Crotalaria rotundifolia* (Walt.) Poir.

Plant perennial, prostrate, and comparatively small; stems 3-6 decimeters long, branched; stipules small, usually sagittate; leaves simple, oblong to oval, rounded at apex, somewhat narrowed at base, pubescent on both sides, 15-20 mm. long, 7-12 mm. wide; peduncles long, 2-6 flowered; calyx 8 mm. long, the teeth somewhat longer than the tube; flowers yellow, 10 mm. long; pod 18-22 mm. long and 8-10 mm. wide, glabrous; seeds 2 to 3 mm. long, brown, matures midyearly; native American species.

This species, producing a fair amount of seed, occurs commonly in the Southern States but has not yet been tested under cultivation.

*Crotalaria sagittalis* L.

Plant annual or perennial, erect, comparatively small, 3-6 decimeters high; stems terete, pubescent; stipules small, sagittate; leaves simple, linear, oblong to oval, 2-6 cm. long and 4-15 mm. wide, pubescent on both sides; peduncles 2-10 cm. long, 2-4 flowered; flowers yellow, 8-12 mm. long, corolla equaling the calyx; pod 18-22 mm. long and 8-10 mm. wide, glabrous; seed small, 2 mm. long, brown, matures midlate; native American species.

Under cultivation this species has made but small growth.

*Crotalaria spectabilis* Roth.<sup>7</sup>

Plant erect, 1-2 meters high, moderately branched, but heavy foliage makes plant appear dense; branches terete, sulcate, nearly glabrous, never woody; stipules large, 2 cm. long, foliaceous; leaves simple, large, long obovate, 12-18 cm. long and 6-9 cm. wide, glabrous above, finely pubescent beneath; racemes mostly terminal, 20-30 cm. long, lax, 30-40 flowered; calyx 12 mm. long, campanulate, teeth broad and as long as the tube; corolla 24 mm. long, yellow with purple tinge, standard and wings striate with light purple lines; pod 4-5 cm. long, 12-15 mm. wide, inflated, glabrous, becoming almost black with weathering; seed large, 5 mm. long, glossy black, matures midlate.

<sup>7</sup> *C. sericea* Retz. = *C. spectabilis* Roth.

*Crotalaria spectabilis* is one of the two species that have been tested somewhat extensively in the Southern States. Large quantities of green manure and good crops of seed have been produced. It has not yet been demonstrated that this species can be used for forage. Its somewhat bitter taste may preclude it for this purpose. At best it would make a coarse hay. The seed habits are fairly good, and in this respect it is one of the best *Crotalaria* species tested. The season of blooming and ripening seed is comparatively short, and it seems possible that the seed crop can be harvested by cutting the entire plant rather than by hand picking the pods, which seems necessary in many other species. At Gainesville, Fla., it is in bloom in July and ripens seed in September and October. Farther north it is somewhat later.

***Crotalaria sphaerocarpa* Perrott.**

Plant, suberect, 3-9 decimeters high, diffusely branched, rounded at base, generally 3-6 decimeters across, rather open top; stipules very small; leaves trifoliate; leaflets oblanceolate, the central one larger than the laterals and 2 cm. long, 8-10 mm. wide, mucronate, nearly glabrous; racemes lax, many flowered, terminal and lateral 8-12 cm. long; calyx 2 mm. long, calyx teeth longer than the tube; corolla yellow, 4 mm. long; pod roundish oblong, small, 4 mm. long and 3 mm. wide; seed brown, very small, 1 mm. long, matures mid-late.

Very limited tests suggest that this species, having rather poor habits, may have some value for both forage and green-manure purposes. However, it has not volunteered or grown so readily as several other species.

***Crotalaria striata* DC.<sup>8</sup>**

Plant erect, 3-18 decimeters high, freely branched, with branches often quite divaricate, plants not symmetrical; stems terete, becoming woody with age; the young branches with a fine gray pubescence; stipules minute, mostly deciduous; leaves trifoliate; leaflets obovate oblong, glabrous above and below, 5-8 cm. long and 3-3.5 cm. broad; racemes terminal, moderately dense, 15-25 cm. long; calyx 6-7 mm. long, teeth equaling the tube; corolla yellow, 12-14 mm. long; the standard distinctly striate with purple lines; pod up to 4 cm. long and 8 mm. wide, glabrescent; seed 2.5-3 mm. long, mottled or sometimes solid; light amber or brown, variable, matures midseason to late.

The large acreage plantings of *crotalaria* in the Southern States have been of this species. *Crotalaria striata* is an upright free-growing plant branching freely in thin stands and making a heavy yield of green manure. While coarse and somewhat woody with age, it can be cut with an ordinary mower. In thick stands when cut in first bloom it has the texture of good hay. In the green state it has a bitter taste, and its value for forage purposes has not been fully determined. Meal made from this species has been fed to dairy cows with good results. It has been demonstrated that it is a good summer green-manure crop, but further work needs to be done with reference to its forage value. This species has fairly good seed habits. At Gainesville, Fla., it has bloomed in June, matured seed in July, and continued to bloom and ripen seed until frost.

***Crotalaria tetragona* Roxb.**

Plant semlerect, attaining a height of 2 meters; branches sulcate, thinly pubescent; stipules small or wanting; leaves simple, obovate oblong, large,

<sup>8</sup> Introductions of *C. striata* from Porto Rico have sometimes been called *C. saltiana*.

15-30 cm. long; both sides thinly silky pubescent; racemes 15-20 cm. long, lax, 6-10 flowered; calyx 2-2.5 cm. long, dense brown velvety pubescence, teeth linear, acuminate, very long; corolla yellow, little exserted; pod 4-5 cm. long, dense brown velvety pubescence; seed large, 5 mm. long, greenish black to nearly black.

Grown in the greenhouse only, it seems to be less well adapted to United States conditions than many other species.

*Crotalaria usaramoensis* Baker.

Plant erect, 1-2 meters high, well branched; stems terete, lightly pubescent, woody with age; stipules very small; leaves trifoliolate; leaflets linear oblong, 5-10 cm. long and 1.5-4 cm. wide, apex subacuminate and base cuneate, glabrous above and below; flowers in long terminal racemes; calyx glabrous, tube 3.5 mm. long, truncate at base, teeth 1.5 mm. long; corolla yellow, standard 10-13 mm. long, striate with light purple lines, carina slightly longer than the standard; pod oblong cylindrical, 3.5 cm. long and 8 mm. wide, becoming black on weathering; seed small, 2 mm. long, amber to red, matures midlate.

This species makes a good growth and is adapted to a wide range of conditions. It appears to be worthy of further attention for green manure, forage, and as an ornamental. Under conditions in the United States it has proved a very sparse seeder, dropping nearly all pods before maturity. At Gainesville, Fla., it has bloomed in June and continued in bloom throughout the season. At Columbia, S. C., it has bloomed in July, ripening some seed in August. In the Netherland East Indies it has been recognized as having forage value.

*Crotalaria valetonii* Baker.

Plant semlerect, bushy, 6-12 decimeters high, divaricately branched, lower branches long and spreading; stems terete, moderately branched, densely villous; stipules wanting; leaves simple, long oval, 6-8 cm. long and 3-4 cm. wide, densely silky villous on both sides; racemes short, lateral, 2-12 flowered; flowers 2-2.5 cm. long; calyx tube 3 mm. long; calyx teeth 10 mm. long, pubescent; corolla purplish yellow, standard decidedly longer than the wings or keel; pods oval, 1.5 cm. long, 1 cm. wide, thinly villous; seed large, 6-7 mm. long, light color, greenish or brownish yellow, matures late.

This species appears to be quite oily throughout, but the quantity is not large enough to be of commercial importance. G. S. Jamieson, of the Bureau of Chemistry and Soils, who examined pods and stems, reported his findings as follows:

The *Crotalaria valetonii* pods have been found to contain 9.24 per cent of oil. The oil which was extracted by petroleum ether was of a dark yellowish-brown color and very limpid. It has an iodine number of 88.2 by the Hanus method, a saponification value of 183.9, an acid value of 169.0, and a refractive index at 25° of 1.4670. The acid value was made within 15 hours after the extraction of the oil was completed. This product consists largely of free fatty acids which in terms of oleic acid amounts to about 85 per cent of the oil. On account of the small oil content, it would seem to have no commercial possibilities.

The seed habits of this species are fairly good, and it has seeded well in southern Florida. However, the general habits of the plant do not make it especially desirable for forage.

*Crotalaria vallicola* Baker.

Plant erect, 6-12 decimeters high, moderately branched, stems cinereous-pubescent; stipules small or wanting; leaves trifoliolate; leaflets elliptic obovate to oblong obovate, the base tending to cuneate, 20-40 mm. long and 10-15

mm. wide, pubescent on both sides; flowers in dense racemes; calyx about 4 mm. long; standard and keel about 5 mm. long, striate with purple lines; pods sessile, 15-18 mm. long, short pubescence; seed small, 2 mm. long, dark brown, matures midlate.

This species has been grown in Florida only and has not made as heavy a growth as many other species and probably has less value. Seed matured at Gainesville, Fla.

#### *Crotalaria verrucosa* L.

Plant semierect, divaricately and sparsely branched, 3-9 decimeters high; stems tending to angular, finely pubescent on young stem; stipules large, 1.5 cm. long, foliaceous, semilunate; leaves simple, irregularly oval to ovate, 4-12 cm. long by 2-8 cm. wide, glabrous above, finely pubescent beneath; flowers 6-20, in lax terminal and lateral racemes; calyx campanulate, 6-7 mm. long, teeth twice as long as the tube, lightly pubescent; standard 14-18 mm. long, greenish white, streaked with pale blue within; wings yellowish white at the base, the rest deep blue; pod 3-3.5 cm. long and 8-10 mm. wide, nearly glabrous when mature, silky pubescence when young; seed 3 mm. long, yellow or yellowish brown, matures midseason.

This species has made comparatively small growth and does not seem to be well suited for United States conditions. At Columbia, S. C., it has bloomed the last of June and ripened seed the last of August. In Florida it has had about the same season.

#### *Crotalaria* sp. 60305.

Plant erect, 6-12 decimeters high, moderately branched; stems small, terete; leaves trifoliate; leaflets linear to linear oblong, 4-8 cm. long, 1-2 cm. wide, tip acuminate to slightly rounded, mucronate, glabrous above, sparingly pubescent beneath; stipules none; flowers in long terminal racemes; calyx tube broadly campanulate, 3 mm. long, lightly pubescent; calyx teeth acuminate, 2 mm. long; corolla 11 mm. long, yellow, standard and wings striate with purple lines; pods cylindrical, 2.5 cm. long, finely pubescent; seed 2.5-3 mm. long, light to reddish brown, matures midlate.

This species has made a good growth in trials in Mississippi and Florida. It is quite leafy and appears to be a good forage type. It matures a good crop of seed and appears as a promising species. It is very closely related to *Crotalaria lanceolata* and may be a variety of that species.

#### SUMMARY

*Crotalaria* is a new crop in the United States, having been first introduced in 1909.

While there are about 600 species, only 36 are reported in this study. Two of these, *Crotalaria striata* and *C. spectabilis*, are being used commercially in the United States, while several others show promise in experimental work.

Both *C. spectabilis* and *C. striata* are upright, short-lived plants that must be treated as summer annuals under conditions in the United States.

All of the *Crotalaria* species tested so far are especially adapted to sandy soils.

The principal use of *crotalaria* is for green manure.

General observation and very limited feeding tests indicate that some of the species can be used for hay, while others probably are poisonous.



The seed ripens over a long period of time, making seed harvesting somewhat difficult.

Most of the seed used in the Southern United States in the last three years (1927-1929) has been imported from Porto Rico. Some seed is grown in Florida.

*Crotalaria* is immune to nematodes and has been free from any serious fungous disease.

The pumpkin bug and the bella moth have been somewhat serious at times on the seed crop.

The organism that inoculates *crotalaria* is widely distributed, and it has not been found necessary to inoculate artificially.

The forage and green-manure yields of *crotalaria* on poor sandy lands in the South have been heavy, and it would appear that this crop has a real place under such conditions.

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